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(54) APPARATUS AND PROCESS FOR RADIATION CURING OF COATED STRIP-LIKE MATERIAL

(71) We, ARMCO STEEL CORPORATION, a corporation organised under the laws of the State of Ohio, United States of America, of 703 Curtis Street, Middletown, Ohio, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention is concerned with an improved and simplified process and apparatus for radiation-curing of coated strip-like material. The invention has particular, but not exclusive, utility with respect to plastic coated metallic base strip. While the latter is not novel per se, it is considerably more recent in development than the other known methods of protecting base materials.

For example, in the early development of metallic coated products, it was found that coatings of aluminum, zinc, or other low melting metals would provide suitable protection for a ferrous base alloy under many environmental conditions. While such coatings provided immediate corrosion protection to the base metal, such protection was limited in time. In addition, it was not a decorative coating nor was it suitable for certain severe conditions.

Concurrent with this development, porcelain enameled coatings were applied to ferrous base materials in order to enhance the appearance of the base material. Thus, such a coating not only gave a decorative appearance to the product, it also provided corrosion protection to the base metal. However, due to the brittle nature of such coatings, the applications were necessarily limited.

The disadvantages enumerated above were greatly minimized by the development of the radiation curable plastics which could be applied to base metals. Such a combination offers the advantages of the flexibility and strength of steel, while giving the superior protection characteristic of the newly developed plastics.

To be more specific on this development, it is now well established that certain materials, when subjected to radiation, undergo unique physical changes. For instance, various organic materials undergo advantageous changes when selectively irradiated. The various polymers are typical of this group as they have been observed to experience multiple cross-linkage when subjected to ionizing radiation. As a result of this cross-linkage, the polymer exhibits different physical characteristics. And, these new characteristics can be used to enhance the performance of the metallic base as a fabricated product.

One of the hazards associated with the provision of radiation-curing is the stray radiation which can affect and/or disable the operator of the system. To protect the operator, elaborate structures have been built. Typically, in the radiation-curing of a continuous strip it is not unusual to find an elongated radiation chamber for treating the strip. Such a chamber minimizes the stray radiation which may leak from the ends thereof. Such apparatus, while capable of coating and curing the strip, is quite complex and occupies valuable floor space.

According to one aspect of the invention there is provided a process for the continuous irradiating of a moving strip, comprising the steps of applying a coating of radiation-curable substance on only one surface of said strip, passing said coated strip through a restricted opening into a chamber containing an electron accelerator, changing the plane of travel of said strip before irradiation thereof by at least 20°, curing said coating by means of said electron accelerator, maintaining said coated surface free of physical contact between the application of said coating to at least the curing thereof, again changing said plane of travel of said strip by at least 20° after curing thereof and removing the strip from said chamber through a restricted opening.

According to another aspect of the invention there is provided apparatus for irra-

diating a moving strip having a coating of a radiation-curable substance on only one surface thereof, comprising a coating station for applying the substance to the strip in an uncured form, a chamber having a radiation section, restricted strip entrance and exit openings to permit the passage of the strip through the chamber from section to section, means adjacent the entrance and exit openings to change the angle of the moving strip twice by at least 20°, said means co-operating with the coating station to prevent physical contact with the coated surface between the coating station and the exiting of the strip from the chamber, an electron accelerator disposed within the radiation section of the chamber and disposed substantially normal to the strip, and means communicating with the radiation section through additional restricted openings to prevent the release of stray radiation to the outside atmosphere.

The invention will now be described in detail, and is illustrated, by way of example, in the accompanying drawing which is a simplified sectional view showing the coating and radiation-curing of a continuous strip-like material in apparatus according to the invention.

The process of this invention provides for a compact system for coating of a strip-like material, such as a ferrous base continuous strip, on only a single side thereof, followed by the radiation-curing of the said coating. A feature of this invention is the provision of disposing the accelerator or electron generator gun at an angle within an appropriate section of a chamber and passing the strip normal thereto. This is accomplished without contacting the coated surface prior to the curing thereof.

More specifically, the strip undergoes two changes in its plane of travel while in the chamber. That is, the strip is coated on the upper surface thereof, passed over an idler roller and then downwardly within the range of the accelerator, and finally upwardly and out of the chamber. This procedure permits the attainment of the desired results in a minimum of space, without jeopardizing the operating personnel due to stray radiation.

With regard to the apparatus of the invention, and referring to the drawing, there is shown a coating and radiation-curing apparatus comprising in sequence, a strip pay-off reel (not shown), a strip-coating mechanism 12, a chamber generally indicated at 10 and comprising three sections which are an entrance section 14, a radiation section 16 containing an electron accelerator 30, and an exit section 18, and finally a strip take-up reel (not shown).

For reasons which may become apparent hereinafter, no attempt will be made to describe the structure or the function of the strip pay-off and take-up reels as these practices per se have long been in existence in the metal, paper, and fabric industries. Accordingly, the description hereinafter will concentrate on the components lying therebetween and as shown in the drawing.

The coating of the strip on only a single side is accomplished by the coating mechanism 12, such as a roller coater 20, with support rollers, or other known means capable of depositing or transmitting a film of a radiation-curable substance such as the various polymers. When subjected to ionizing radiation these substances experience multiple cross-linkage of the molecules to form a solid adherent coating on the base material.

After coating, the strip with the "wet" coating on one side which remains untouched by rollers or external means enters the entrance section 14 of the three-section chamber 10 through a restricted opening 22, where it passes over one or more rollers 24 supporting the underside thereof. Roller 24 works in conjunction with roller 26 to maintain the strip under sufficient tension during its passage through the radiation section 16 of the three-section chamber 10.

Restricted openings which permit passage of the coated strip with only slight clearance from one section to the other of the three-section chamber 10 are essential to safe operation of the apparatus. One of the potential problems of apparatus of this type is the hazard caused by stray radiation. From a health standpoint, exposure of the operating personnel to any concentration of radiation may be detrimental to their physical well being. For this reason, all communicating ports within and without the apparatus are minimized.

Further, radiation shielding structural members, such as thick concrete beams or blocks are used throughout. These are the primary materials, although others are known and available, to form the enclosing and intermediate walls of the sections 14, 16 and 18 of the chamber.

Returning now to the strip travel, it will be seen from the drawing that the strip passes downwardly from the section 14 through a restricted opening 28 and past the accelerator 30 to effect the curing of the "wet" coating. The downward travel of the strip continues through a restricted opening 32 to pass from section 16 around a roller 26 where it begins an upward movement into and through the third section 18 from which it moves out of the chamber to pass to the take-up reel.

From the application of the "wet" coating to the strip, until finally cured, the coated surface does not contact any external means which could affect the uniformity of the

coating. This then represents one of the advantages of the compact system taught herein. Further, by providing two changes in the plane of the strip travel through the chamber as opposed to a relatively straight line, it is possible to accomplish the desired results in a minimum of space. That is, if the strip were to pass into, through, and out of the chamber in substantially a single plane, an unusually long chamber would be necessary to ensure dissipation of the radiation.

The above may be more effectively demonstrated when it is considered that a strand of steel as thin as 0.19 mm (0.0075"), and travelling at a speed of up to 30m/min. (100 fpm) can be suitably cured in the radiation section 16 whose length is no greater than about 3m (10 feet). Using the apparatus shown in the drawings, this means the strip passes through the radiation section 16 at an angle of about 30° to the horizontal, for a distance of about 2.4m (8 feet) before passing into the exit section 18. The speed of the line or strand is dependent upon the radiation dosage required to cure the coating, and not the strip gauge. Thus, a strand having a thickness well above 0.19 mm (0.0075") may be employed in this apparatus.

Prior to the strand's entry into the chamber 10, it is provided with a "wet" coating on a single side thereof with a radiation-curable substance. The substance may comprise a polymer dissolved in a monomer base, which when irradiated, generates free radicals which cross link with the polymer molecules. This causes a chain reaction and the eventual curing or thermosetting of the final film. This film, when cured, may be as thin as 0.005 mm (0.2 mils) or as thick as 0.25 mm (10 mils). In practice, the final application for the product will dictate the film thickness desired.

Whilst different accelerators or generator guns may be suitable to effect the curing of the polymeric coatings, one which has been used with success is one manufactured by the High Voltage Engineering Corp. Such an accelerator is rated as having a 400kv insulated core transformer with a 50ma insulated core accelerator. When the accelerator is positioned so that there is approximately 146mm (5.75") between the strand surface and the accelerator scanner window, it has been found that the above mentioned accelerator will cure the polymeric coating noted above prior to its contact with the roller 26. However, it should be remembered that the conditions stated above are presented solely for the purpose of illustration as being representative, and that they should not be read as limitations on the invention.

Variations are contemplated for the apparatus described herein. For practical considerations, a single stationary accelerator can cover or irradiate a specified area. However, when multiple, scanning or wide band accelerators are involved, a much larger area or strand width can be used. Thus, the strand width forms no restriction to the invention herein. In addition, the strand angle within the radiation section 16 may vary between about 20—90° from the entrance and exit angles of said strand. In other words, this does not restrict the angular displacement of the strand within the chamber relative to any given plane. While the preferred embodiment shows the strand angled relative to a horizontal plane, it should be apparent that the significant feature here is to insure an angular change between the planes formed by the entering and exiting strand, and the strand while in the radiation section of the chamber 10.

WHAT WE CLAIM IS:—

1. A process for the continuous irradiating of a moving strip, comprising the steps of applying a coating of radiation-curable substance on only one surface of the strip, passing the coated strip through a restricted opening into a chamber containing an electron accelerator, changing the plane of travel of the strip before irradiation thereof by at least 20°, curing the coating by means of said electron accelerator, maintaining the coated surface free of physical contact between the application of the coating to at least the curing thereof, again changing the plane of travel of the strip by at least 20° after curing thereof, and removing the strip from the chamber through a restricted opening.

2. A process according to claim 1, wherein each angular change is at least 30°.

3. A process according to claim 1, wherein the strip enters the chamber at a first location and exits at a second location vertically displaced therefrom.

4. A process according to claim 3, wherein the accelerator is directed towards the moving strip at a point substantially midway between the first and second location.

5. A process according to claim 1, wherein the strip traverses a substantially linear path during the curing step.

6. Apparatus for irradiating a moving strip having a coating of a radiation-curable substance on only one surface thereof, comprising a coating station for applying the substance to the strip in an uncured form, a chamber having a radiation section, restricted strip entrance and exit openings to permit the passage of the strip through the chamber, from section to section, means adjacent the entrance and exit openings to change the angle of the moving strip twice by at least 20°, said means co-operating with

the coating station to prevent physical contact with the coated surface between the coating station and the exiting of the strip from the chamber, an electron accelerator disposed within the radiation section of the chamber and disposed substantially normal to the strip, and means communicating with the radiation section through additional restricted openings to prevent the release of stray radiation to the outside atmosphere.

7. Apparatus according to claim 6, wherein the last mentioned means are separate entrance and exit sections of said chamber, and the first mentioned means are rollers disposed within the separate sections.

8. Apparatus according to claim 6 or 7, wherein each separate section is provided with an additional roller such that the strip is again angularly displaced.

9. Apparatus according to claim 6, 7 or 8, wherein each said angular displacement is at least 30°.

10. Apparatus according to claim 7, wherein the moving strip is coated with said radiation-curable substance prior to its passing into the entrance section.

11. A process of continuously irradiating a moving strip substantially as herein described with reference to the accompanying drawing.

12. Apparatus for irradiating a moving strip constructed and arranged substantially as herein described with reference to, and as shown in, the accompanying drawing.

13. Coated strip when produced by the process set forth in any one of claims 1 to 5, or claim 11.

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1353831 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*